Industrial Technologies Program

Robot-Human Control Interactions in Mining Operations

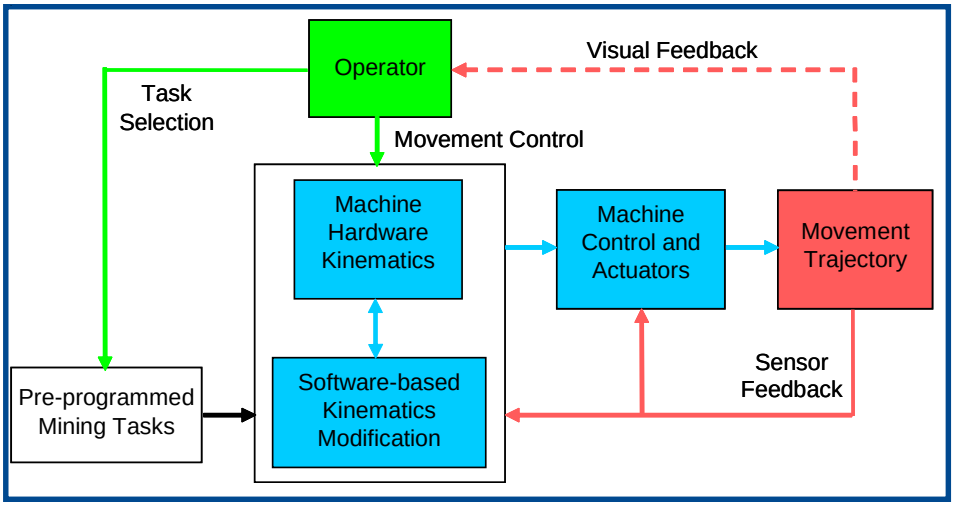
User-Friendly Interface Creates Efficient Machine Control Between Mining Operators and Robotic Equipment

Mining machines are characterized by multiple, articulated joints, using hydraulically or electrically powered elements. Many tasks require a human operator to coordinate the movement of several machine links by simultaneous control of numerous joysticks or other control devices. Robotics used in the manufacturing industry cannot be aptly used for the support of mining machinery operations for three reasons: the complexity of mining operations, variability of the tasks, and the changing environment that is unstructured and requires adjustments during operation.

The University of Nevada, Reno (UNR), along with Newmont Mining Corporation and the Bobcat Company, an Ingersoll-Rand business, are developing an innovative robot-human control architecture for typical surface mining operations in which coordinated movement of several machine links is required. The basic concept of the new robot-human control interaction is to provide real-time operator support using automatic coordination of the machine joints motion. The new control architecture transforms the machine kinematics to the most suitable one for a given task, and trains the machine's control computer to operate a coordinated movement pattern.

During execution, the operator retains the master control of the overall trajectory parameters and the motion velocity, while the machine movement is controlled "by wire". In addition to convenience and manual flexibility, the new control architecture allows for the optimization of the machine during operation.

Employment of a human operator, even in a supervisory capacity, is contrary to traditional industrial robotics practice. In mining, however, flexibility and diversity of operations are required, and the key technical issue is the integration of the partial or full-time adjusting control functions of a human operator, even when a robotic machine is utilized.



Functional Block Diagram of the New Robot-Human Control Architecture

Benefits for Our Industry and Our Nation

- *Reduces energy consumption by up to 15% due to improved loading efficiency and cycle times.*
- *Reduces loading cycle times by up to 30%.*
- *Reduces cost for training machine operators.*
- *Saves several $million for one unit production per year based on benefits.*

Applications in Our Nation's Industry

The mining industry partners may promote the application of this new technology to large mining shovels and other machinery. The results of this project may evolve into a commercial control technique to support a large variety of multilink hydraulic machinery with robotic elements that is currently manually controlled. Initial focus is on surface mining, but further research may yield promise for underground operations.

Project Description

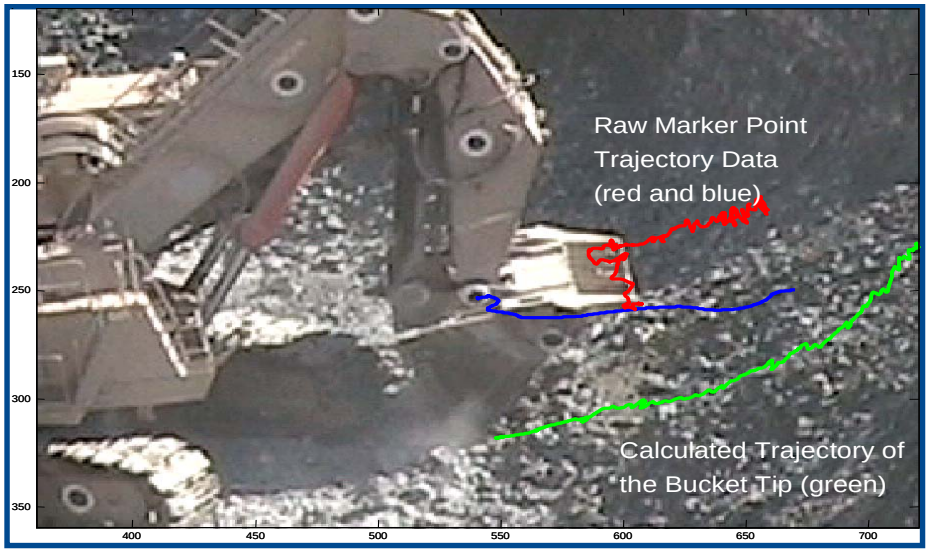
Objective: To evaluate a new concept that integrates robotic control with the human operator in typical mining machines that have multiple links, require coordinated motion of such links, and typically perform cyclic and repetitive operations.

There are three phases to this project. In the first phase, a small robotic excavator will be prepared for tests with a new man-machine interface. A commercial Bobcat® excavator will be retrofitted with a robot control hardware and software system. The new control architecture will then be implemented on the machine. In the second phase, mining tasks will be emulated for basic, bench-scale tests with the new man-machine system. Tests and evaluation will be made with the participation of the industrial partners. In the third task-specific phase, scaled mining field tests will be performed for the evaluation of the man-machine system. The scaled field tests will evaluate the applicability, working efficiency, energy saving, ease-of-operation and other potential benefits of the new concept and technology for large-scale mining operations. The results will be communicated to the industry in order to promote application of the new control technique.

Upon successful completion of the project, Bobcat Company may use the results for commercial application on front-end loaders and excavators. The mining industry partners may also promote the application of the technology to large mining shovels and front loaders by contacting other equipment manufacturers. The results will therefore affect a significant segment of the manufacturing and mining industry. The application of the results by other companies will also be promoted by publications. The results may evolve into a commercial control technique to support a large variety of multi-link hydraulic machinery with robotic elements that are currently manually controlled.

Milestones

- Develop retrofit robotic excavator with new man-machine interface hardware and software.
- Perform basic bench-scale tests emulating simple mining tasks.
- Perform scaled mining field tests and man-machine system evaluation for industrial application.



As part of the development, the motion of a large mining front shovel is being analyzed using camera vision and modeling techniques.

Project Partners

University of Nevada, Reno
Reno, NV

Newmont Mining Corporation
Lone Tree Complex, NV

Newmont Mining Corporation
Twin Creeks Mine, NV

Bobcat Company, an Ingersoll-Rand business
West Fargo, ND

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
Energy Efficiency and Renewable Energy

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